



PEM Fuel Cell Power Modules, Systems, and Applications

CARB Zero Emission Vehicle Symposium
Sacramento, California
Sept 25-27, 2006

Changing power
...Powering change



Agenda

- Introduction to Hydrogenics
- Fuel Cell Power Modules and Systems
- Fuel Cell (Hybrid) Applications
- Closing Remarks

Company Profile

- **Established in 1995**
- **Three business units**
 - OnSite Generation
 - Power Systems
 - Test Systems
- **Global Presence**
 - Canada: Toronto & Vancouver
 - Belgium
 - Germany
 - Japan
 - USA
- **Listed on NASDAQ (HYGS) & TSX (HYG)**
- **300 employees**
- **87 patents awarded; 550 pending**



Business Units and Markets

OnSite Generation



- Industrial Hydrogen
- Refueling Stations

Power Systems



- Backup Power
- Mobility

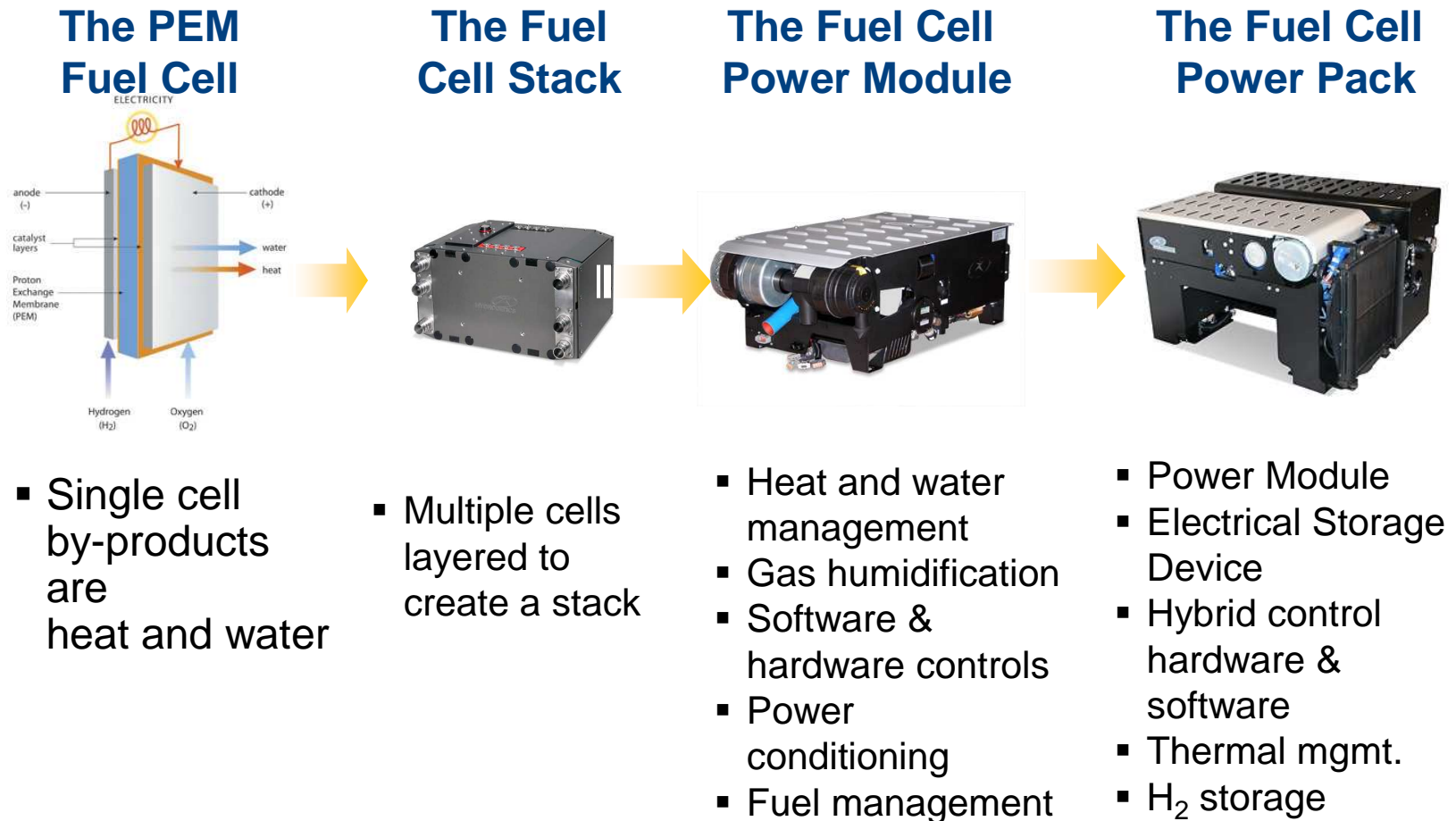
Test Systems



- Test Stations
- Diagnostics
- Test Services

Fuel Cell Power Products

Core competency from PEM fuel cell to complete solutions:



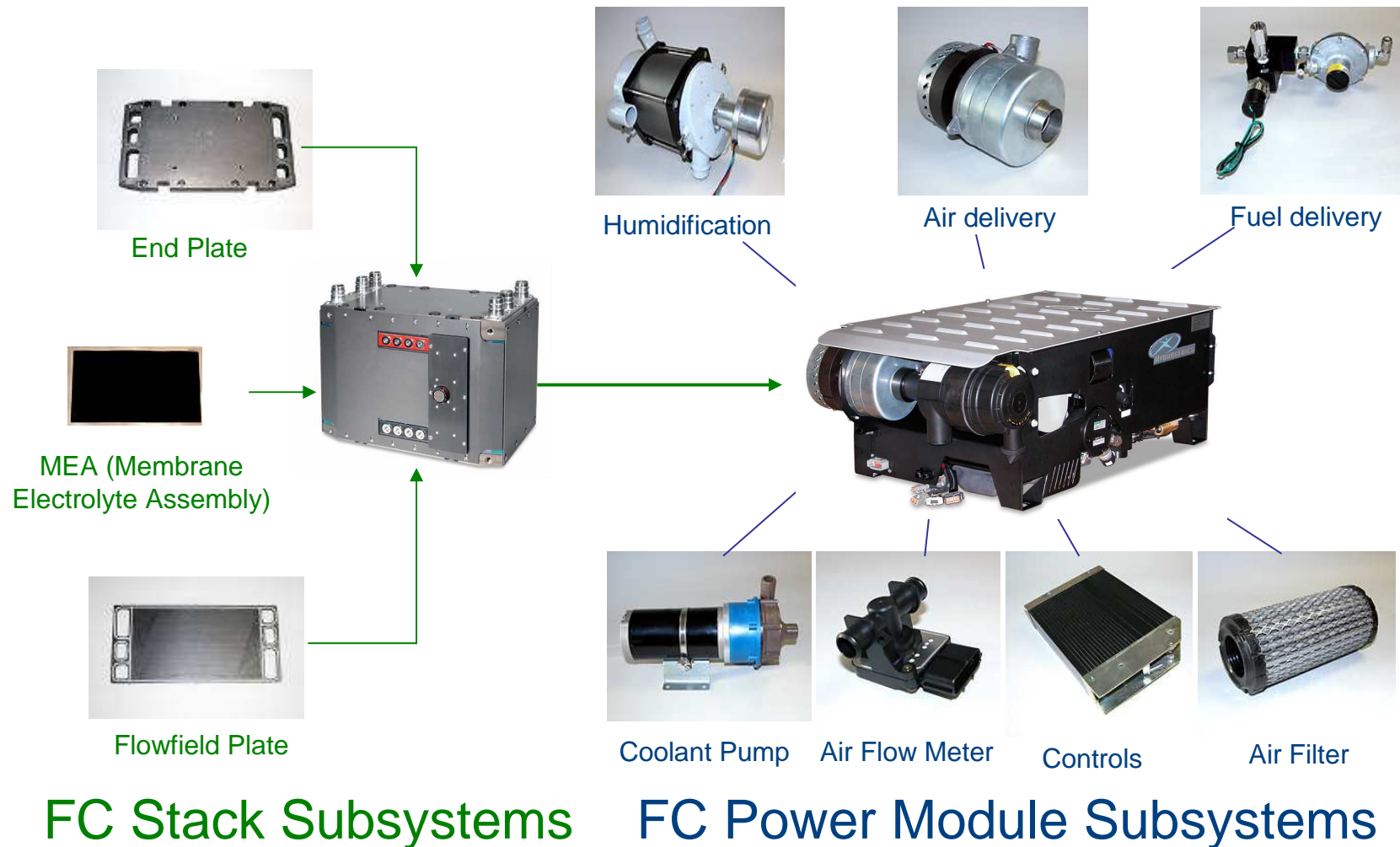
HyPM® Standard Fuel Cell Products



Range of Fuel Cell Power Products targeting specific needs

- Fuel Cell Power Modules for OEMs and SIs- 8, 12, 16, 65 kW
- DC Power Solutions – Fuel cell power module integrated with power conditioning packages to deliver specific nominal voltages - 24, 36, 48, 72 Volts, suited to diverse end user needs
- Fully integrated Fuel Cell Power Packs consisting of fuel cell power module, thermal management, power conditioning, energy and hydrogen storage for end user applications

HyPM® Fuel Cell Power Module Technology



HyPM Fuel Cell Power Pack

Fully Integrated Solutions Fits Existing Battery Compartment



Electrical and H₂ Storage



HyPM Power Module



Thermal Management



Power Conditioning



Fuel Cell Applications – Back-Up Power and APUs



Fuel Cell Applications – Light and Off-Road Mobility

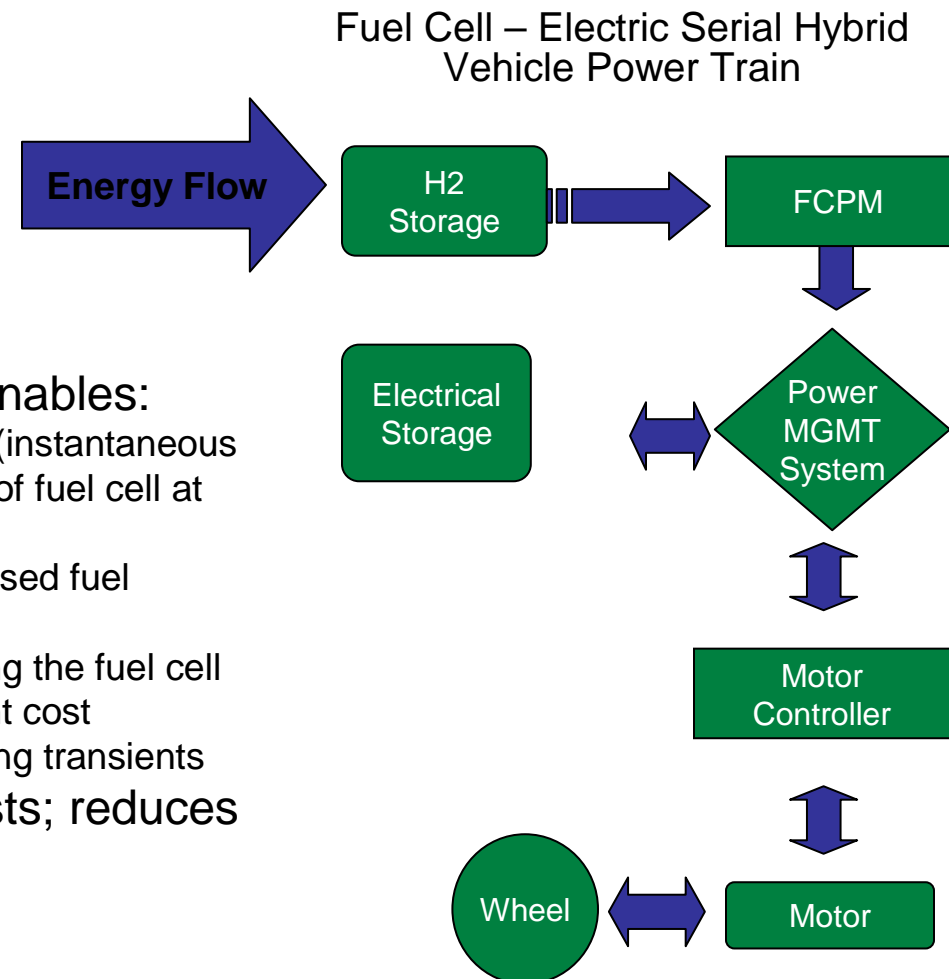


Fuel Cell Applications – Medium and Heavy Mobility



Fuel Cell – Electric Hybrid Benefits

- Hybrid combines Fuel Cell with Electrical Storage Device:
 - Ultracapacitors
 - Batteries
 - Flywheel
- Modes of operation:
 - Acceleration
 - Steady State
 - Braking
- Electrical Storage Device enables:
 - Improved system performance (instantaneous power response and operation of fuel cell at optimal efficiency range)
 - Regenerative braking for increased fuel efficiency
 - reduces system cost by reducing the fuel cell size; reduces stack replacement cost
 - Increases durability by smoothing transients
- Reduces Development Costs; reduces time to commercialize



HyPM Fuel Cell Power Pack

Application: Class 1 Lift Trucks

- Operating voltage is 48 VDC
- 1.6 kg of hydrogen at 350 bar (5000 psi) – enough fuel for an entire shift
- 10 second cold start
- Instantaneous warm start
- Refuel in under 2 minutes





Fuel Cell Powered Lift Truck

Power Train Specifications

Configuration	Fuel cell- ultracapacitor electric hybrid
Fuel Cell Power Module	12 kW
Peak Power (10seconds)	27 kW
Hydrogen Storage	1.6 kg @ 350 bar

Vehicle Specifications

Lift Truck Type	Hyster E55 Class 1 Lift Truck
Lifting Capacity	2300kg (5000lb)
Wheels	Four (4)
Tire Type	Cushion Tire



Benefits of Fuel Cell Power Packs in Lift Trucks

- Releases No Harmful Emissions
- Increases Productivity:
 - Enables fast refueling <5 minutes
 - Provides consistent, abundant power
 - Offers extended run (1.7 shifts per fill – in an 8-hour shift)



Levels of Hybridity

Vehicle Examples

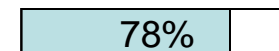
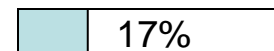
Fuel Cell Pwr / Motor Cont Rated Pwr

Fuel Cell Power as a Percentage of Motor Power

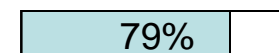
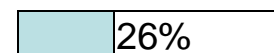
Hydrogen (kWh_e) as a Percentage of Total kWh_e cap.



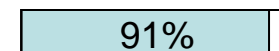
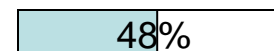
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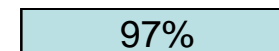
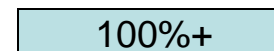
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Fuel Cell Hybrid Midi Bus



Fuel Cell Hybrid Midi Bus



Overview

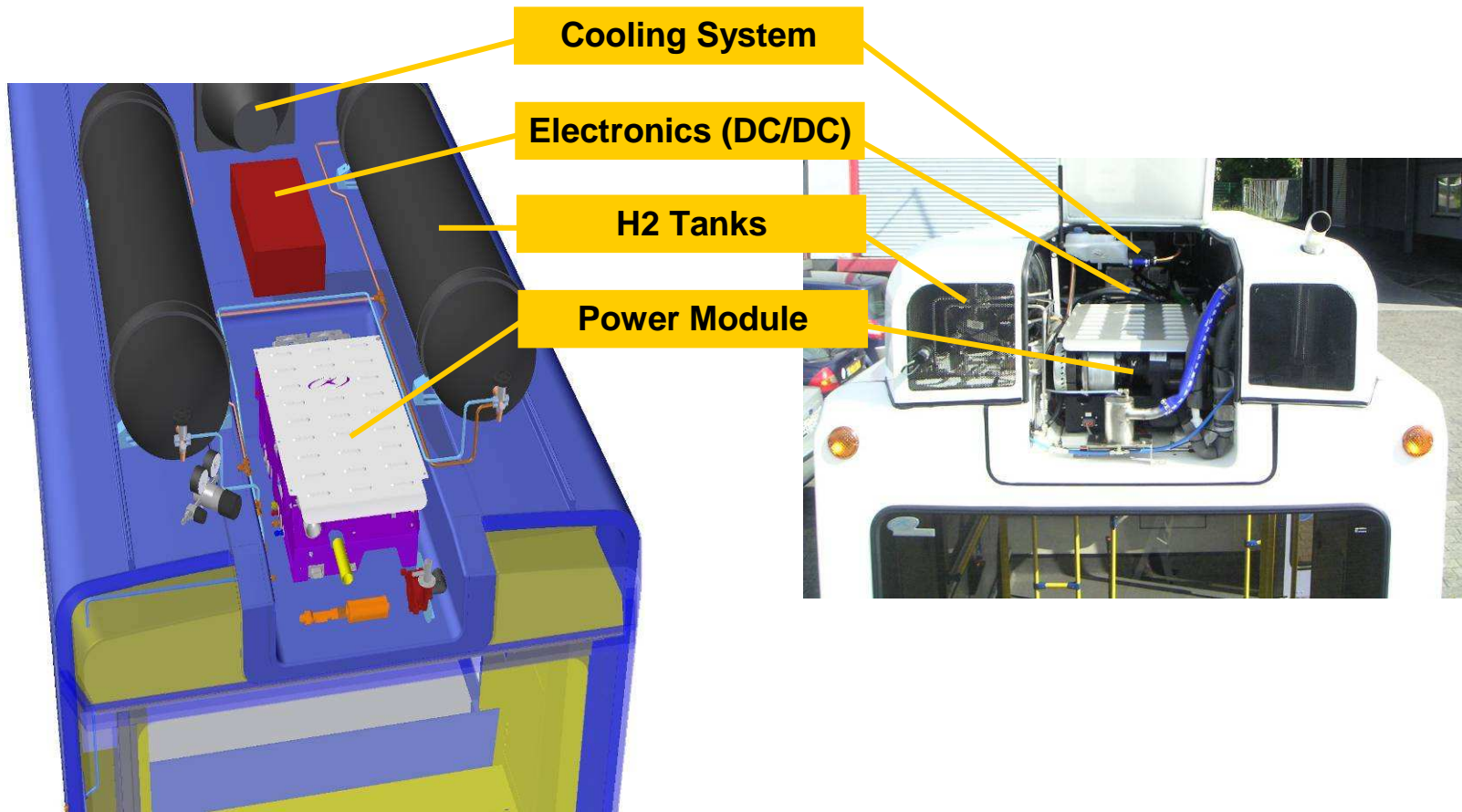
Technical Data

Length	5.3 m (17 ft)
Type	Low floor
Seats	8
Max speed	33 km/h (20 mph)
Autonomy	200 km (125 mi)
Drive	12 kW PEM Fuel Cell
Motor	25 kW
Fuel	Hydrogen
Hydrogen storage	5.8 kg @ 2850 psi
Energy storage	NiCd Batteries



Fuel Cell Hybrid Midi Bus

Location of Main Components

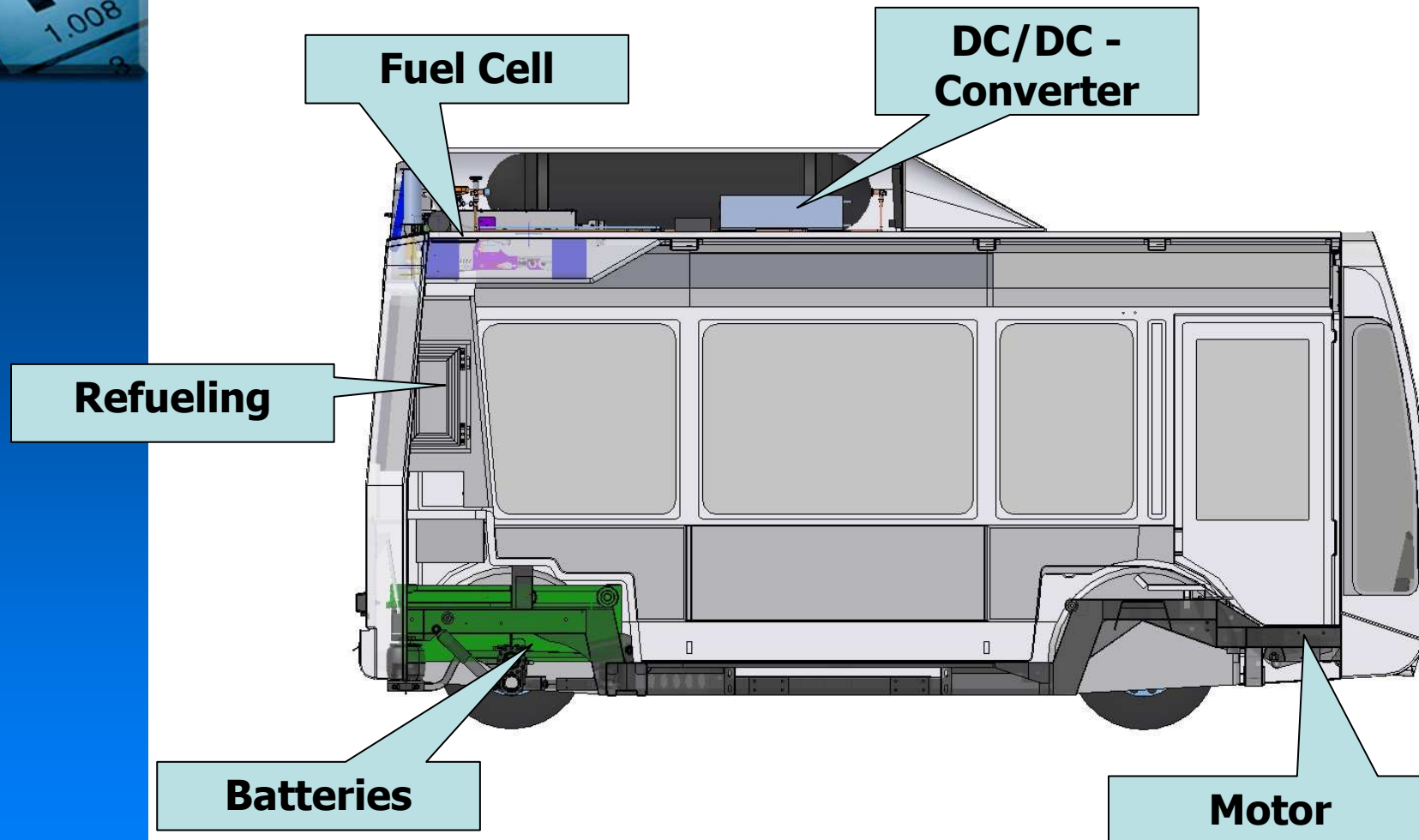


Planning

Execution

Fuel Cell Hybrid Midi Bus

Location of Main Components



Hickam AFB Fuel Cell Bus



Hickam AFB Fuel Cell Bus



Technical Data

Length	30 ft (9.4 m)
Type	High floor
Seats	23
Max speed	60 mph (100 km/h)
Autonomy	125 mi (200 km)
Drive	20 kW PEM Fuel Cell
Motor	120 kW
Fuel	Hydrogen
Hydrogen storage	10 kg @ 350 bar
Energy storage	Lead Acid Batteries

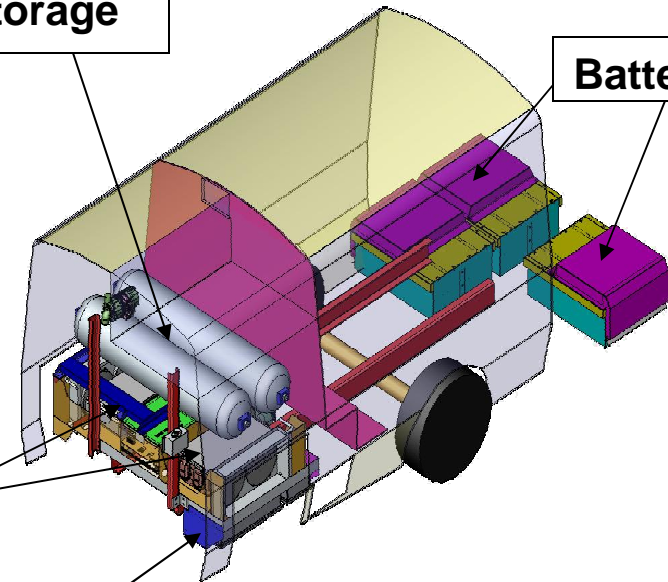


H₂ Storage

Batteries

Fuel Cells

Control Electronics Unit





Closing Remarks

- It is important how the fuel cell stack is treated, therefore it is important how the balance of plant and system components are chosen/designed and system integrated.
- Fuel Cell technology is ready for early deployment in certain stationary and mobility markets
 - Backup Power
 - Forklift Trucks
 - Hybrid Buses
- Fuel Cell mobility solutions are better if combined with energy storage
- Hybrid solutions will accelerate the commercialization of fuel cell technology
- Consider battery dominant, fuel cell, plug-in hybrid systems as a new viable powertrain architecture



Thank you!

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...Powering Change